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AN EVALUATION OF A SHIPBOARD COLLISION AVOIDANCE DISPLAY

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Background: Navigating a ship at night in close proximity to another vessel is a dangerous task. To increase the conning officer's situational awareness, we propose a visual navigation display mounted on the stern of the aircraft carrier that will assist shipboard conning officers when maneuvering in a battle group formation. **Methods:** To test the effectiveness of the visual navigation display, the aircraft carrier and plane guard vessel were modeled in a virtual environment. **Results**: The navigation display condition had significantly fewer range and bearing errors than to the non-navigation display condition. The navigation display provided immediate feedback as to whether the aircraft carrier had changed bearing or speed, thus enabling the operator to initiate the appropriate input to maintain station astern of the carrier. **Conclusions**: Actual or potential applications of this research include combatants conducting plane guard duties astern of an aircraft carrier during flight operations and ships in underway replenishment waiting station.

INTRODUCTION

Operating a surface combatant at night in close proximity to an aircraft carrier can be one of the most challenging and dangerous evolutions at sea. During this plane guard task, the aircraft carrier is launching and recovering aircraft while the surface combatant is positioned a few thousand yards astern of the carrier. The conning officer's attention is divided between gauging the location of the aircraft carrier, monitoring aircraft traffic, searching the water for other vessels, and avoiding foreign obstacles. To accomplish these tasks, the combatant's conning officer must estimate the aircraft carrier's distance and bearing by visual and auditory information; however, in certain situations these cues may be ambiguous which may lead to a loss of situational awareness by the conning officer. To reduce the loss of situational awareness, we propose that a Tactical Vectoring Equipment (TVE) be mounted on the stern of the aircraft carrier that will assist shipboard conning officers when maneuvering in a battle group formation (Evanoff, 1999).

The TVE display consists of six red and white lights spaced approximately six feet apart mounted on the stern of the aircraft carrier. The TVE's position on the carrier's stern will be clearly visible to the escort ship conning officer, but will be invisible to the carrier pilots during flight operations. To test whether the TVE will improve conning officers' situational awareness compared to the standard red, green and white aircraft carrier navigation running lights, aircraft carrier and plane guard surface vessel were modeled in a virtual environment. We hypothesize that the TVE display will enable the conning officer to track an aircraft carrier significantly better than the normal shipboard lighting condition. The TVE's red and white light configuration will enable the conning officer to easily discriminate range and bearing of the stern of the aircraft carrier in relation to the combatant ship, thus the TVE will increase conning officers' situational awareness during battle group formation.

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METHODS

Observers: Thirty military observers with normal or corrected to normal vision volunteered for this experiment. Fifteen subjects were designated as Surface Warfare Officers (SWO) and the remaining fifteen subjects were designated from non-SWO communities. Informed consent was obtained from all observers.

TVE display: The TVE navigation display is similar to the aviation runway displays that assist pilots during low illumination or poor weather conditions. These landing displays may use Fresnel lenses or lasers (Martenak, 1999) to display multi-colored lights to the pilot to indicate the plane's vertical position in relation to the runway. For example, if the pilot's glide path angle were too low then the runway display would appear red indicating to the pilot to increase power. The TVE display uses similar principles, except the shipboard display is positioned horizontally on the stern of the carrier (Figure 1).

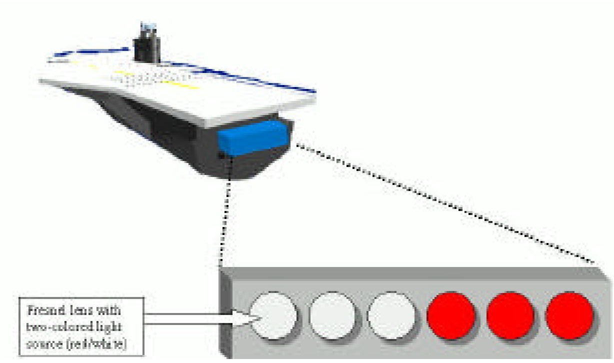

Figure 1. The TVE shipboard navigation display. The TVE display consists of a horizontal line of six bicolor (red and white) lights spaced approximately six feet apart on the stern of the carrier.

The position of the carrier relative to the combatant, the TVE will illuminate different combinations of red and white lights to indicate the escort ship's relative position to the stern of the carrier. The TVE will provide the conning officer instantaneous, continuous, and positive visual feedback of the carrier's position relative to the cruiser. For example, if the cruiser was 200° left of the stern of the carrier, then the TVE display would illuminate one white and five red lights to indicate the approximate number of degrees off station (Figure 2) – the desired station is 175°.

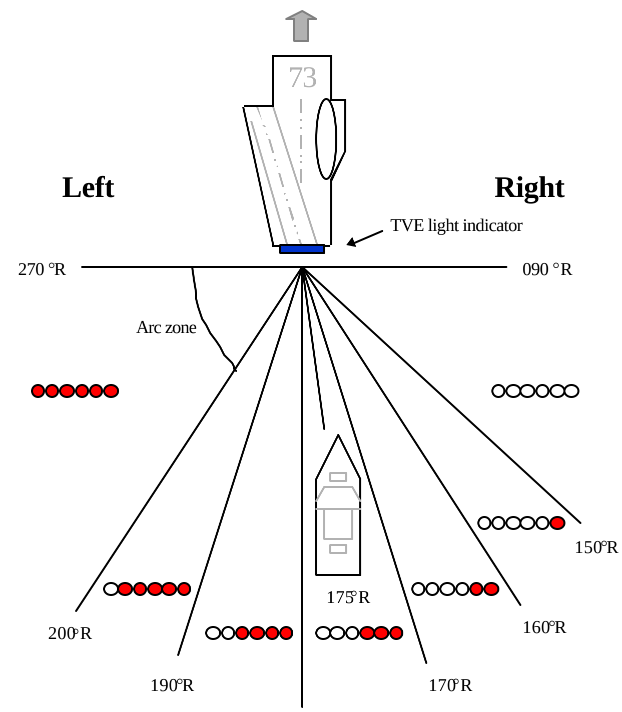

Figure 2. The red and white color system indicates the escort ship's relative position astern of the carrier. The desired station is 175° relative. As the ship's position changes relative to the carrier's stern, the light display changes color indicating approximate degrees off station. The conning officer can also interpret the aircraft carrier's range by the size and spacing of the lights from the combatant vessel.

Procedure: Subjects viewed the virtual environment through a Virtual Research V8 head-mounted active matrix LCD VGA display with a field-of-view of approximately 60 degrees. Head positions were tracked with a 3space Polhumus tracking system and the ship position was manipulated by a BG Systems FlyBox joystick. The virtual environment was rendered on a Silicon Graphics Onyx Reality Engine. Software used to model the simulation was MultiGen Creator (version 14.5), Vega (version 3.2), Vega Marine module (version 3.2), and LynX graphical user interface (version 3.2) from MultiGen-Paradigm Inc.

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The subject was exposed to thirty static images: two lighting schemes (normal shipboard lights or TVE light display), three ranges (225, 300, or 375 yards), and five bearings (135°, 165°, 175°, 200° or 225° relative). On each trial, the static stimulus appeared for three seconds on a 31” monitor followed by a five-second blank screen. The subject's task was to indicate the direction and distance of the aircraft carrier relative to the position of the astern ship during the five-second blank interval. At the completion of the thirty static slides, the subject participated in the dynamic experiment.

The dynamic experiment consisted of two randomly assigned blocks of animated trials. Each block consisted of either five TVE display trials or five normal shipboard lighting display trials. Within each block of trials, five different carrier course tracks were randomized for each subject. The carrier course tracks consisted of a 20° port turn, 70° port turn, 20° starboard turn, 70° starboard turn, or a steady course. The subject's task was to maintain station 175 degrees relative at 300 yards astern of the aircraft carrier for each of the five course track changes (Figure 3).

The time, position and heading of both ships were recorded by the computer every five seconds and saved onto a data file for follow-on analysis. The experiment ended when all ten trials were completed.

RESULTS

Static Trials: A 2x2 Analysis of Variance (Group by Display) with bearing error as the dependent measure showed subjects were significantly better using the TVE display compared to the normal shipboard display (F (1, 56) = 33.03, $p < 0.01$). Subjects were 98.7% accurate while viewing the TVE display, and 84.4% accurate with the normal lighting display. The six errors committed in the TVE condition were recorded by non-SWOs.

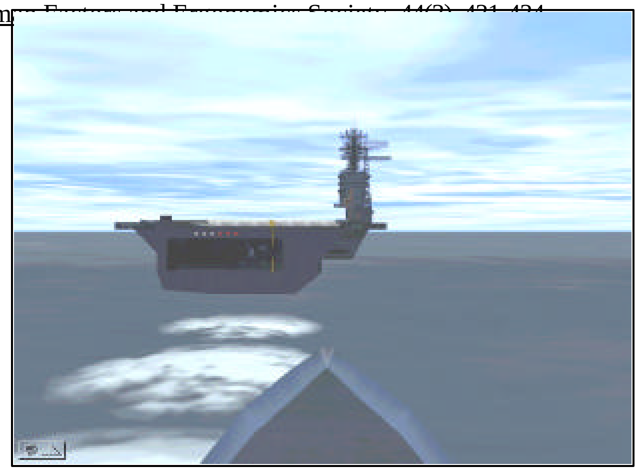

Figure 3. The observer was positioned on the deck of the surface combatant and required to maintain station behind the carrier by issuing rudder and engine orders to the experimenter. On this trial, the carrier accelerated from 0 to 15 knots while maintaining a steady course for 15 seconds, then executed a 20° turn to starboard approximately 90 seconds into simulation, then maintained a steady course and speed after completing the turn.

Subjects using the TVE display estimated range significantly better than the normal lighting display (F (1, 56) = 11.56, $p < 0.01$). Overall, subjects committed more range errors than bearing errors; however subjects were 55.8% correct using the TVE display, while the normal lights recorded 47.8% correct.

Dynamic Trials: A power transformation of log (Y) was used to normalize the range and bearing errors. A 2x2x5 (Lighting Display by Group by Carrier Course Track) MANOVA was conducted with the transformed range and bearing errors serving as the dependent measures. Significant main effects were found for Lighting Display (Pillai-Bartlett Trace, F (2, 279) = 11.04, $p < 0.01$); Groups (Pillai-Bartlett Trace, F (2, 279) = 4.85, $p < 0.01$); Carrier Course Tracks (Pillai-Bartlett Trace, F (8, 560) = 29.00, $p < 0.01$). Interactions failed to show any significant effects.

Subjects committed fewer bearing errors with the TVE light display than with the normal lighting display (F (1,280) = 5.20, $p < 0.02$). SWOs were significantly better than non-SWOs (F (1,280) = 7.18, $p < 0.01$) with 8.7^0 and 10.7^0 mean bearing error for the TVE and normal lighting display, respectively.

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Similarly, the non-SWOs performed better in the TVE condition than with the normal lighting condition, 10.7^0 and 13.9^0 mean bearing error respectively.

Range error was significant for Lights (F (1,280) = 20.85, $p < 0.01$) with SWOs committing smaller errors for the TVE display compared to the normal lighting display, 66 yards and 93 yards respectively. Non-SWOs mean range errors were significantly higher than SWOs (F (1,280) = 5.0, $p < 0.03$), yet non-SWOs estimated range better with the TVE display than with the normal lighting display, 78 yards and 116 yards respectively.

Figure 4 illustrates a dynamic trial for a SWO observer. The experienced SWO using the normal shipboard lighting display was unable to track the carrier (figure 4a); however, the same observer committed no errors when the TVE was used (figure 4b). The observer's situational awareness was increased with the TVE.

Figure 4. Illustrates a dynamic trial of the carrier turning 070° starboard. (a) The SWO initially tracked the carrier, but became disoriented after the carrier started its turn. The subject, unsure of the carrier's movement, reversed direction to avoid a collision then initiated full forward momentum to catch the carrier. (b) The SWO immediately detected the carrier's starboard turn. The subject crossed the carrier's wake; stayed outside the wake until the carrier steadied on the 070° course heading; then proceeded back across the wake to regain plane-guard station. This was a textbook example of a proper ship maneuver when following a carrier.

Figure 4 (a)

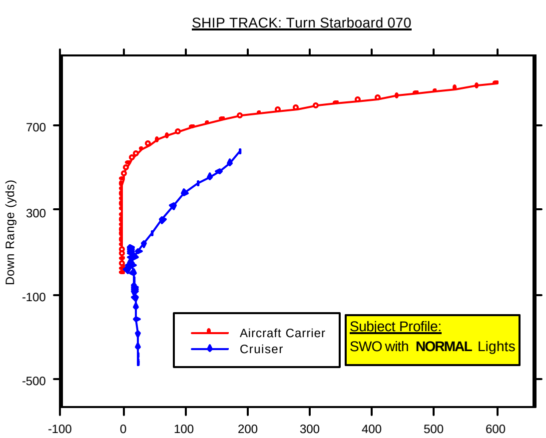
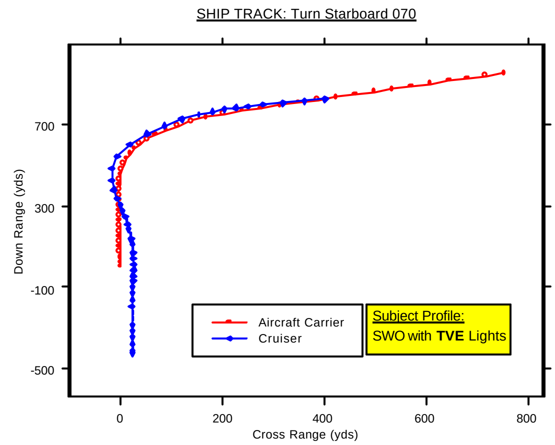


Figure 4 (b)



CONCLUSION

This research strongly suggests that military observers committed fewer errors in estimating bearing and range with the TVE display as compared to normal shipboard lighting configurations. This study suggests that using the TVE navigation system enhances conning officers' situational awareness. The TVE system provides the conning officer the necessary visual locomotion cues to interpret relative motion between ships.

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